APPENDIX A
TO U.S. PATENT
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DISTRIBUTION
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ATTORNEY DOCKET
NO: WT-15

Calimetrics' MultiLevel Technology Enables Higher-Performance CD/DVD Recorders

An IDC White Paper

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Introduction

MultiLevel (ML) recording technology represents an exciting new development in optical data storage. This technology has the potential to solve the cost and backward-compatibility issues that have prevented greater-than-CD capacity optical recording from becoming widely adopted.

Initial ML drives target a threefold increase in CD capacity to 2GB per disc and a 36x CD or 5.4MBps data transfer rate for writing (based on a 12x standard CD spindle rate), thereby providing much higher-speed recording than any CD or DVD system has been able to deliver to date. Future CD and DVD products based on ML will be able to easily incorporate technology improvements and continue to stay ahead of the industry's technology road map.

The combination of these factors opens up new applications for the optical data storage market, as higher-capacity and higher-speed recording at low cost essentially turns the CD-R/RW drive from a digital photocopying machine for duplicating audio CDs into:

- A true high-performance data storage peripheral for the PC
- A high-capacity, high-performance, and low-cost medium for digital video editing
- In small form factor (50-80mm), an exciting new way for CD technology to be used in handheld, portable, and Internet appliance applications

In addition, ML technology has gained the support of several major companies in CD and DVD recording. Calimetrics and TDK have formed the ML Alliance to commercialize ML technology. Mitsubishi Chemical and Plextor have joined this alliance.

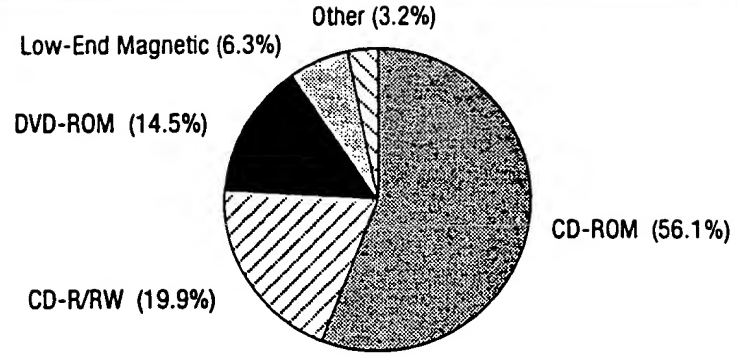
Optical Storage Overview

The optical storage market can be divided into three areas: CD, DVD, and other optical technologies, including magneto-optical (MO) and proprietary phase-change technologies.

CD formats have reached true mass-market volumes. CD-ROM drives have shipped in most PCs for the last five years. CD-R/RW has expanded CD-ROM's success into the rewritable market. Already in 1999, it outshipped the low-end removable magnetic drives (primarily Iomega's Zip and SuperDisk) in its peak year, reaching 17.2 million units worldwide.

DVD, which will ultimately replace CD, is also on the verge of reaching mass-market levels. DVD-ROM will lead the way for DVD recorders once the installed base of compatible DVD-ROM drives is comparable to current CD-ROM levels. The market shares for all other optical formats are small in comparison (see Figure 1).

Figure 1
Estimated Worldwide Removable Drive Technology Share, 2000



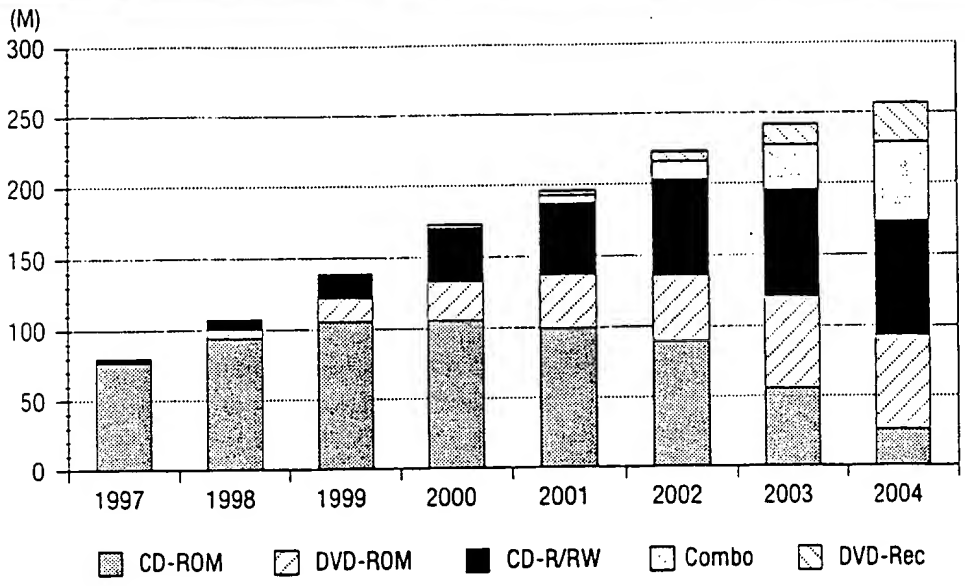
Source: IDC, 2000

CD and DVD Formats

As shown in Figure 2, IDC's forecast of the 120mm optical market calls for additional significant unit growth exceeding 250 million in 2004. The addition of the CD-write and the DVD-read features to the basic CD-ROM drive will be the two major trends in the market for the next five years.

Clearly, CD-ROM compatibility will be the basis to which additional features can be added. IDC believes that CD-ROM volumes will peak in 2000 and that we will see a gradual decline as more and more

Figure 2
Worldwide 120mm CD/DVD Drive Market



Source: IDC, 2000

mainstream PCs ship with CD-RW or DVD and only the very price-sensitive low end of the PC spectrum ship with just a CD-ROM drive. Some corporate PCs in particular will stay with CD-ROM because it is sufficient for software installation.

CD-RW will be the largest segment, replacing CD-ROM, followed by DVD-ROM. From 2003 onward the Combo Drive (CD-RW and DVD-ROM) will become important. Also, in the later years we will see one or more flavors of DVD-Rec (DVD-RAM, DVD-RW, DVD+RW) become important.

Much of CD's success is based on the following factors:

- Compatibility
- Affordability
- Content

As a standard-based technology, CD achieved excellent compatibility. Even as CD added recording and rewriting functionality to some drives, the impact on media interchange has been small. CD-R is readable in virtually any of the 500 million CD-ROM-compatible drives worldwide. CD-RW had some initial incompatibility issues. However, for more than two years, the clear majority of CD-ROM drives have been able to read CD-RW media. The beauty of CD-RW drives has been that if compatibility is required, they can record a CD-R and a CD-RW with the same ease.

CD-ROM drives have seen very steep price declines from over $100 OEM in 1995, their breakthrough year, to below $30 in 2000. Leveraging the CD Audio Player experience allowed the industry to reduce cost and increase speed at the same time. CD-RW has now also fallen below the important $100 OEM price point and has become affordable in many high-end and mainstream PC configurations.

Content is a key driver for CD technology. Besides the plentiful CD audio title choices, virtually any computer software is available on CD-ROM. Again, CD-R/RW has added significant value because now average users are able to create customized content. Users can burn custom audio recording, photo albums, and experimental software on inexpensive CDs for easy interchange or archiving.

Additionally, CD-R is replacing the floppy diskette as the medium of choice for general interchange of data. The inexpensive floppy has served well in this application for over 20 years. However, as the typical file size has increased over the years, its 1.44MB capacity has become insufficient for almost everything besides plain text. CD-R is a good fit to replace the floppy because it combines compatibility and low media cost (<$1 for a CD-R) with much higher capacity (650MB).

Besides the trend for CD-RW to become the de facto floppy replacement, there is a more formal initiative underway with the same goal. It is called the "Mount Rainier Initiative," and it is supported by Sony, Philips, Microsoft, and Compaq. Its goal is to provide true "drag-and-drop" functionality for CD-RW drives on the PC. This shows that already, even without ML, the market is moving toward CD-R/RW as the "floppy of the future."

Nonetheless, even CD-R 650MB is not sufficient for all applications of removable storage. In particular, full system backup and video applications typically require more than 1GB of storage. Today, the hard drive of a typical PC has over 10GB of storage. As this capacity fills up, a system backup would span several CD-R/RWs.

High-quality, full-screen video is another key area where CD capacity is insufficient if users want to record more than a few minutes. As end users get more and more accustomed to DVD-quality video, the storage capacity of removable media will also need to increase in order to satisfy this fast-growing application.

There is also the emerging market for mobile consumer devices, which require high capacity and fast recording. Audio, digital photography, and video will be the dominant applications. Many of these devices will require small form factor media.

CD is a good fit due to its capacity, compatibility with a large installed base of CD players and CD-ROM drives as well as inexpensive and rugged media. There is also an intangible factor, and that is that CD media are familiar to consumers. This could play to the advantage of

CD-based optical storage systems as they require no new introduction to users. However, capacity beyond what standard small form factor CDs can provide will be important, especially for video recording.

CD recording has debuted in digital cameras in the form of the 80mm CD-R-enabled Mavica Camera from Sony. Clearly, the high capacity and low cost of the media, and the fact that by default there is automatically a permanent backup copy of the digital image on the CD, have end users excited. Additionally, the easy interchange of the CD between the camera and virtually any PC eliminates the need for cables or adapters.

Limiting factors for optical recorders are the cost of the drive and physical integration into the host device. Physical size of the drive and power consumption will continue to be challenges in mobile or battery-powered mobile devices.

Besides ML recording, which is discussed later in the paper, several other technologies, such as DVD-Rec and double-density CD (DDCD), go beyond CD capacity.

DVD-Rec Drives

DVD-Rec drive shipments, which include DVD-R/RW, DVD-RAM, DVD+RW, and similar formats, have shipped in only very modest volume. Despite the fact that three vendors — Panasonic, Hitachi, and Toshiba — are now shipping DVD-RAM in production volumes, IDC believes that market acceptance will continue to be sluggish in 2000.

Several reasons account for the relatively low DVD-Rec (mostly DVD-RAM at this time) shipments, including compatibility, competing formats, price, capacity, and functionality. One of the main reasons for this slow acceptance is the small installed base of DVD-ROM drives and DVD-Video players that can read DVD-RAM media. Another reason is market confusion due to the presence of several competing formats for DVD recording, including DVD-RAM and DVD-RW (endorsed by the DVD Forum) and DVD+RW (supported by six major CD-RW vendors, including initial DVD Forum members Philips and Sony). Additionally, DVD-Rec's high prices, compared with those of CD-RW, limit its sales to the aftermarket and even more to PC OEMs. Capacity has been more of a psychological issue for first-generation DVD-RAM with 2.6GB capacity per side because DVD-ROM holds up to 4.7GB on one side. Also, unlike CD recording, which allows easy copying of audio CD, DVD recorders lack the same killer application because DVD movies are copy protected. Additionally, current DVD-Rec drives are backward-read compatible but not write compatible (they cannot record CDs), and CD-RW has become an increasingly important feature on many PCs.

However, in the near future, new products will address most of these issues, and IDC believes that long-term DVD recording will become a common feature on most PCs.

One reason why DVD-Rec drives have been more expensive is that DVD uses a red laser, instead of the infrared laser used in CD technology, to achieve the necessary higher density. Therefore, to be able to also be compatible with CD technology a second laser and additional optics are required. Bridging backward compatibility to CD and forward compatibility to all major DVD formats is one of the major challenges for DVD-Rec technology.

Double-Density CD

In August Sony announced the purple book double-density CD-ROM/R/RW. This format is designed to achieve higher density without requiring red laser technology. This technology achieves 1.3GB capacity — twice that of CD — which is a significant improvement, but not enough for full system backup (typically at least 2GB) or at least one hour of DVD-quality video, a minimum threshold for users. DDCDs are written with a standard infrared CD laser in combination with a new, more powerful lens; therefore, DDCD drives require a new optical head as well as new electronics. Write speeds remain constant, so the DDCD drive takes twice as much time to record a DDCD as a standard CD. Once recorded, DDCDs cannot be read in standard CD-ROM drives. Nonetheless, DDCD could have a delaying effect on DVD-Rec if the technology delivers on its promise to only marginal cost increases over current CD technology. The spirit of DDCD is to extend current technology without requiring a major, often expensive, technology leap. With this incremental approach, DDCD is similar to ML technology.

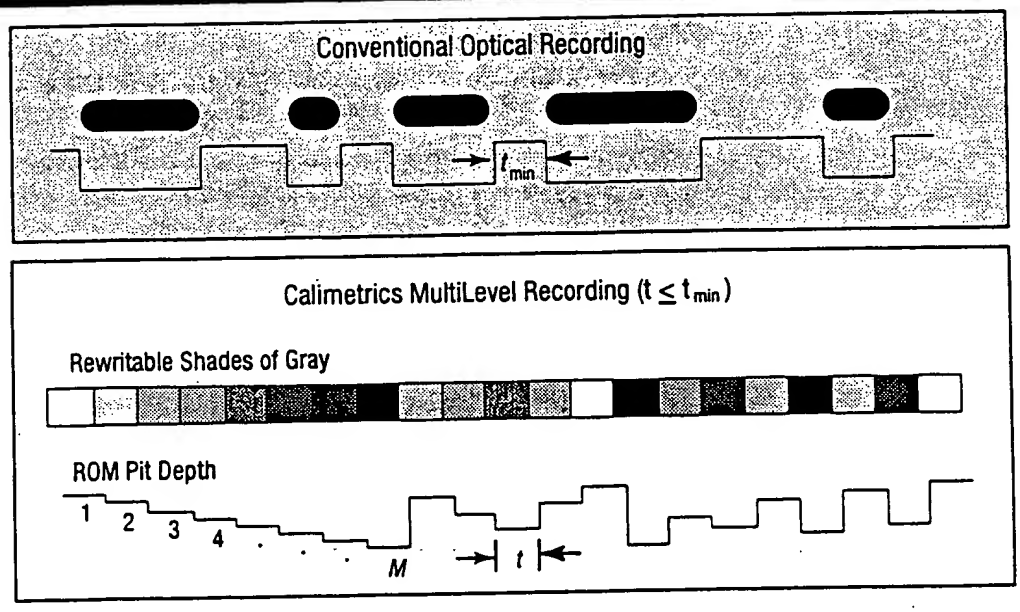
Background on ML Technology

Calimetrics and its partners in the recently announced ML Alliance utilize proprietary MultiLevel Recording™ techniques that can provide 3x or more increase in the storage capacity and native data transfer speed of today's standard CD and DVD optical drives and disc media. More importantly, this 3x improvement can be made without altering existing optics, mechanics, or manufacturing infrastructure. Further, a single ML chip, for writing and reading ML-encoded discs, integrates directly onto existing onboard electronics for standard optical drives so that backward compatibility with legacy CD and DVD discs can be retained. Also, the technology is forward compatible and can provide further improvement as blue lasers, new lenses, and dual-sided recording technologies are introduced.

ML Technology for Writable Optical Systems

As shown in the top part of Figure 3, in a conventional writable optical disc drive, the laser writes and reads a series of marks of uniform darkness or reflectivity on the disc. These marks are of different lengths and are used to encode data.

Figure 3
Conventional Versus MultiLevel Recording



Source: Calimetrics, 2000

With MultiLevel Recording,™ Calimetrics creates marks of different lightness or darkness — different levels of reflectivity (see bottom part of Figure 3). Each mark is roughly the same small length. But now with MultiLevel Recording,™ more information can be written and stored in each data cell on the disc. For example, in the space where a 0 or 1 was previously stored, MultiLevel Recording™ can store values from 1 to 8 (or more). As a result, the same space on the disc now stores more information, increasing the capacity for the same surface area of the disc. In a read-only system, those multilevel marks are actually pits of physically different depths, which create the effect of multiple levels of reflectivity to the reading laser. Calimetrics calls this technique Pit-Depth Modulation for ROM discs.

For writable and read-only discs, MultiLevel Recording™ also increases the data transfer rate of the system. When writing and reading, the laser in a conventional optical drive is essentially used as an "on-off" switch, either writing or reading a mark or the absence of a mark. In MultiLevel recording, the laser can now write and read more information in the same space on the disc. For example, in an eight-level system, three bits, or three times as much information, can be recorded in a

single mark in the same (or less) time as it takes to record one bit in standard recording. When combined with high-bandwidth electronics, MultiLevel Recording™ provides significantly increased data transfer rates for writing and reading.

Unlike many alternative approaches, optical drives based on MultiLevel Recording™ technology will not require new materials or advances in laser technology. Current CD and DVD drives only require one new integrated circuit, plus disc media fine-tuned for MultiLevel Recording,™ in order to achieve significant increases in capacity and speed.

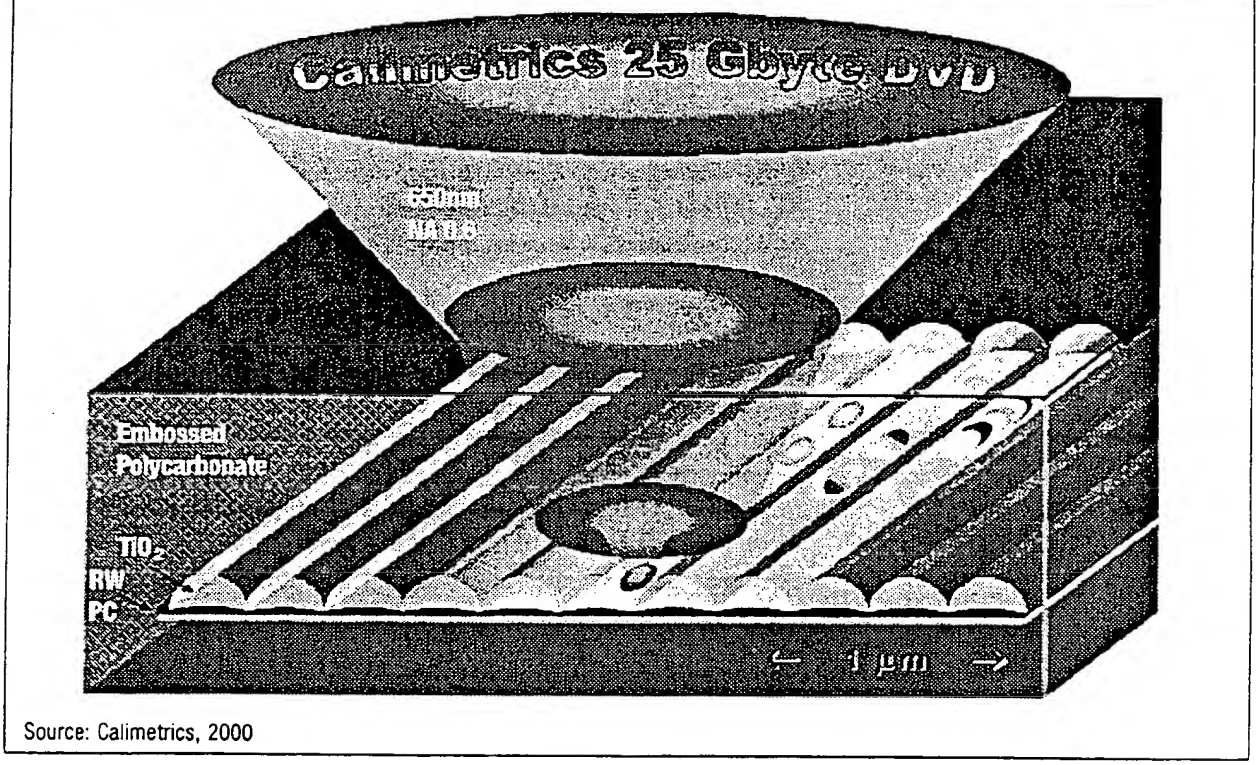
Integral Near-Field Optics Multiplies ML Capacity Improvements

Beyond the 3x improvements due to MultiLevel recording, Calimetrics' Integral Near-Field Optics technology provides an additional 2.5x to 3x multiplier to the data capacity of reflective optical storage systems such as CD and DVD. Unlike other types of near-field recording, this technology is implemented without flying the optical head very close to the disc media, thereby solving a major technical problem that has delayed commercialization of near-field technology in removable optical data storage systems. In combination with Calimetrics' proprietary MultiLevel Recording™ technology, the Calimetrics' near-field technology provides approximately eightfold increases in the data recording capacity of CD-R and CD-RW systems, to 5GB per disc, and approximately fivefold increases to recordable and rewritable DVD formats, to 25GB per disc (see Figure 4). These gains are achieved without changing the lasers, optics, and mechanical components of the base systems.

To understand how Integral Near-Field Optics works, some background is needed: Optical data storage capacity is determined by the size and spacing of the marks that can be written by a laser diode that is focused by a lens onto the media, and then read back by the same lens. The size and spacing of the marks are determined by the wavelength of the light used, as well as the diameter and focal length of the lens (Numerical Aperture or N.A.). Accordingly, a shorter wavelength laser diode and higher N.A. lens provide higher storage capacity, as seen in DVD and CD products.

With near-field optics, significantly higher numerical apertures can be achieved, thereby increasing the storage capacity. One implementation is done by using a hemispherical lens, made from a material with a high refractive index, that is "flown" very close to first surface media (meaning the recording layer and data are on the top of the media), as part of a flying head. The laser light from a conventional (far-field) optical module focuses just below the lens, a fraction of a wavelength of light away — hence the term "near-field." The focused spot is made smaller by the high refractive index, which shortens the effective wavelength of the laser light, and numerical aperture of the lens. However,

Figure 4
Integral Near-Field Optics



Source: Calimetrics, 2000

the near-field effect requires that the distance between the first surface media and the flying lens be approximately 100nm. Efforts to develop near-field storage, especially for removable media, have been slowed by the difficulty of maintaining such a small distance between the flying lens and the media surface (known as the head-media interface), especially for removable media.

However, Integral Near-Field Optics works differently. Calimetrics' near-field technology is achieved by embedding proprietary structures within the media itself that work with the normal far-field lens-to-media surface placement of CD and DVD drives to achieve the smaller and more closely spaced marks, thereby increasing capacity. The recording layer and data are embedded and protected deep in the media and, just as with DVD and CD, the media is removable. Integral Near-Field Optics is illustrated in Figure 5.

The Integral Near-Field technology is currently under development by Calimetrics. Like Calimetrics' Multilevel Recording™ technology, the near-field technology can be added to existing CD and DVD systems at very low incremental cost, primarily through use of up to two ASICs as well as refined/reformulated disc media manufactured using existing processes. The technologies will be combined to yield 5GB CD-type products and 25GB and greater DVD-type products.

Market Impact of ML Technology

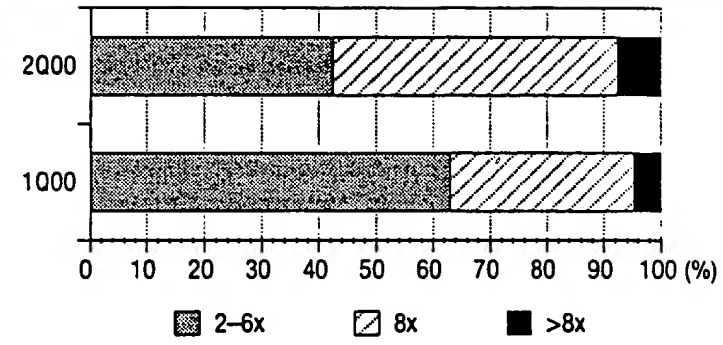
ML technology is positioned to play a major role in:

- Traditional PC-attached optical opportunity
- High-performance segment
- Emerging consumer opportunity

Higher capacity and performance is desirable for everyone. However, PC OEMs are very price sensitive and have to shop for the best available technology for each product line while still hitting the targeted price points.

In the PC world, starting with distribution in aftermarket channels, the high-end segment typically evolves into the next mainstream technology as prices decline and volumes increase; then PC OEMs begin to adopt. Once that happens, normally a new, higher-performance segment emerges. Figure 5 shows how 8x CD-RW has transitioned from a high-end product in 1Q00 into the next mainstream CD-RW drive, replacing 4x drives. Also, 10x and 12x CD-RW drives have expanded their presence at the top of the performance spectrum and are poised to move into replace 8x drives within the next two quarters.

Figure 5
Worldwide CD-RW Shipments by Speed, 1Q00 and 2Q00



Source: IDC, 2000

For PC applications, MultiLevel Recording™ has the potential to offer PC OEMs and their customers significantly higher capacity and performance benchmarks for any given standard CD-R/RW drive's cost and base spindle speed.

In addition, MultiLevel Recording™ can help PC OEMs and their customers reduce cost and increase system functionality. One CD-R/RW drive with MultiLevel Recording™ provides all removable data storage functions in a single, low-cost device:

- Data distribution, delivered with a CD-ROM drive
- Data interchange, provided by the floppy disk and CD-R drives
- Near-online storage capability, provided by high-capacity floppy, tape and removable hard disk drives

Another market opportunity is the emerging consumer device that uses CD-R technology. Examples are Philips' Double Deck consumer CD recorder and Sony's Mavica CD-R digital camera. In particular, for the mobile consumer applications, small, ideally palm-size devices are critical. For example, a number of companies, including IDS Ltd., are working on developing handheld MP3 audio recorders that utilize small form factor, low-cost CD recording technology instead of expensive flash RAM. Therefore, small form factor removable storage becomes essential. It is therefore no surprise that Sony's digital camera uses the smaller 80mm CD format. However, smaller form factors require greater data density, because end users still demand sufficient capacity for their applications.

For all the preceding market opportunities, performance is as important as capacity. Capacity by itself has limited benefits for the end user if it takes too long to record it. One lesson that can be learned from the floppy replacement battle is that even though the choices have vastly more capacity (100–650MB compared with floppy's 1.44MB), the user still expects that new technologies should not take longer to record a disk. Performance and capacity increases must go hand-in-hand. Users expect higher capacity from their removable drives over time but expect that they can record one disc at least as fast as the old technology.

ML in the Context of Current Market Trends

ML technology addresses the following critical factors needed for success in the CD/DVD drive market:

- Capacity
- Speed
- Low incremental cost
- Backward compatibility
- Forward compatibility with new formats

ML technology arrives at higher capacity by packing more bits into the same physical space on an optical disc without requiring shorter wavelength lasers or additional optics. The data rate is increased by the same factor as the capacity because ML electronics can read and write more data in the same physical space without spinning the media faster.

Calimetrics' goal is to minimize the incremental cost of ML-enabled CD and DVD drives. This will be critical. As discussed in the previous two sections, users will perceive ML technology as one more new

feature. A useful example is the addition of CD-RW capability to CD-R drives a few years ago. Initially, when launched in 1Q97, CD-RW drives cost 25% more than standard CD-R drives of a similar speed — a significant price premium. By 1Q98, the CD-RW price premium over CD-R declined to less than 5%. However, ML technology also offers significantly higher write speeds than standard CD-R/RW drives, and the market has shown a desire to pay a significant price premium for write speed increases much smaller than the 3x improvements ML technology promises to deliver. For example, 12x drives at introduction commanded $50-100/drive price premium over 8x drives at retail, and $20-50/drive price premium in the OEM channel, during the first year after their launch. MultiLevel Recording™ technology promises to triple the performance of drives with 12x spindle speeds to 36x, while the remainder of the industry will be offering drives that record only at 12x to 16x maximum rates.

Backward compatibility with today's CD technology is clearly one key requirement for any new mass-market optical technology. ML technology delivers on this important requirement. In fact, it is designed to achieve CD-R/RW compatibility without requiring additional optics or mechanical components.

For many casual users, the value of higher capacity and performance from ML technology is at least initially much smaller than the value of CD-R/RW recording. Even though ML CD-RW drives offer significant additional functionality, its true value will become apparent to users as the installed base of CD-ROM drives builds that can read ML CD-R/RW media. CD-ROM drives manufacturers can achieve read compatibility with ML discs with the addition of some electronic circuitry; no changes to drive optics or mechanics are required. In the meantime, ML offers the user a high-capacity storage functionality for personal storage.

Marketing Challenge

ML technology offers significant additional functionality over regular CD or DVD drives without compromising the drive's CD or DVD recording performance. However, the increased choice of media also increases the complexity of the product. ML-enabled CD-RW drives can record CD-R, CD-RW, and ML CD media, all with different levels of compatibility. Therefore, Calimetrics and its partners must educate the end user about compatibility and incompatibilities of CD-R, CD-RW, and ML CD discs. However, Calimetrics has, with TDK and Mitsubishi Chemical, media partners that pioneered the introductions of CD-R and CD-RW media. So, while this is a challenge, the alliance has the experience to adequately address the challenge.

Also, typically each media type will have different write and read speeds. This means that the drive could easily have four or more performance parameters, all of which must be explained to the user.

End users will need to be able to easily identify ML media. Otherwise, they might try to record it in a regular recorder, which could lead to user frustration and many tech support calls. This could be done with a logo or by color coding ML media.

Conclusion

MultiLevel Recording™ technology is a promising new development in optical data storage and has the potential to solve the cost and backward-compatibility issues that have prevented greater-than-CD capacity optical recording from becoming widely adopted.

The capacity and performance of ML technology opens up new applications for optical data storage products including a high-performance data storage peripheral for the PC, a high-capacity, high performance, and low-cost medium for digital video editing, and in small form factor (50-80mm), an exciting new way for CD technology to be used in handheld, portable, and Internet appliance applications.

The support of ML technology by Calimetrics, TDK, Mitsubishi Chemical, and Plextor lends credibility to the timely commercialization of the ML product family.

ML technology could extend the life of CD technology by several years if ML enabled CD-RW drives cost only marginally more than regular CD-RW drives and significantly less than DVD recorders that can also record CD-R/RW media.

ML technology is also positioned as a bridge product between CD and DVD technologies. It fills the capacity range in-between CD and DVD by staying close to CD technology and cost. Therefore, ML technology enables applications which normally would require DVD technology with much fewer limitations than CD technology. Video is probably the one key application. With 2GB, ML technology is able to handle about one hour of DVD-quality video for recording and editing. Once users are accustomed to these new applications and the price for DVD recorders has declined further, it will be an easy transition to DVD.

Calimetrics' near-field recording technology could add again to the useful life span of CD technology by pushing the capacity to 5GB. This would fully close the gap to DVD and allow users to choose between two types of high capacity media: DVD media, which will have forward compatibility with an increasing installed base, and near-field ML media, which will have easier compatibility with the CD installed base.

The same value proposition can be repeated with DVD to push the technology easily to 25-50GB. This capacity range enables over two hours of HDTV-quality video. Again, ML technology enables a technology to extend far beyond its original goal.

The initial focus on CD-RW is the most promising initial implementation of ML technology. CD technology has reached universal user acceptance and will continue to grow strongly. By the end of 2001, IDC expects the worldwide installed base of CD-R/RW drives to exceed 100 million. CD recording will have become such a common feature in PCs that users will expect this capability from newer drives. Therefore, DVD-RAM and other higher-capacity drives that choose not to be able to record a CD will have a clear disadvantage over backward-write-compatible drives.

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